Trends in Food Science & Technology 84 (2019) 52–54

Contents lists available at ScienceDirect

Trends in Food Science & Technology

journal homepage: www.elsevier.com/locate/tifs

Review

Future challenges in seafood chemical hazards: Research and infrastructure needs

António Marques[a,b,*], Ana L. Maulvault[a,b,c], Maria Leonor Nunes[a,b]

[a] Division of Aquaculture and Upgrading (DivAV), Portuguese Institute for the Sea and Atmosphere (IPMA, I.P.), Lisbon, Portugal
[b] Interdisciplinary Centre of Marine and Environmental Research (CIIMAR), University of Porto, Porto, Portugal
[c] MARE – Marine and Environmental Sciences Centre, Faculty of Sciences, University of Lisbon (FCUL), Lisboa, Portugal

ARTICLE INFO

Keywords:
Food safety
Toxins
Chemical contaminants
Research needs
Infrastructure needs

ABSTRACT

Background: Seafood safety is a priority for all stakeholders associated with supply and consumption. Outbreaks and recalls caused by microbial pathogens, toxins from harmful algal blooms and xenobiotics are attributed to contaminated seafood, leading to considerable public health and economic burdens. Yet, the complexity of seafood safety management systems in a dynamic global market affected by climate change and driven by market demands, urges the implementation of innovative research and infrastructures to ensure the safety of seafood products.

Scope and approach: This review presents the major needs in seafood safety research and infrastructures, as far as chemical hazards are concerned.

Key findings and conclusions: Faster exchange of information and establishment of synergies across countries and continents, simplified and efficient food safety policies for stakeholders, innovative and applied research that is useful for stakeholders, and maximizing the use of updated infrastructures, are some of the needs to meet seafood safety challenges in the Ocean of Tomorrow.

1. Current situation

The seafood chain is extremely complex with several actors involved from different countries and continents, including producers, processors, distribution channels, wholesalers, retailers and consumers. Globalization of seafood supply and the increasing global population growth have created favorable conditions for outbreaks of emerging contaminants. Most seafood risks cause three types of illnesses: a) acute infections caused by bacterial, viral and parasitic sources (Behravesh, Williams, & Tauxe, 2012; Marques, Nunes, Moore, & Strom, 2010; Mead et al., 1999; Rodgers et al., 2016); b) acute intoxications caused by toxins produced by micro-organisms and algae (the latter are also known as marine biotoxins); and c) chronic exposure to environmental chemical compounds (Marques et al., 2010). This requires permanent monitoring and implementation of mitigation solutions by food safety authorities and policy makers for anticipating hazard outbreaks that can be effective in protecting public health and ensuring safe, nutritious, high quality and affordable seafood to consumers. According to the 2015 European Rapid Alert System for Food and Feed (RAASF) data, the third highest number of food safety alerts in Europe occurred with seafood (358 alerts), representing 14% of all alerts in 2015 (2556 alerts) (RASFF, 2016). Currently, several challenges put seafood supply under severe stress, compromising the availability of safe, high quality and sufficient products for consumers. Among others, these challenges include: socio-economic and demographic imbalances, climate change, increasing complexity of the supply chain, food security, emergence of anti-microbial resistant strands and novel contaminants of emerging concern, and lack of suitability of the current risk assessment procedures for new seafood ingredients, products, allergens and related technologies.

The current review aims to provide an overview about the seafood safety research and infrastructure needs, as far as chemical hazards are concerned, which can be divided into toxins from micro-organisms and chemical contaminants.

1.1. Toxins from micro-organisms and from microalgae

The main seafood-borne intoxications are caused by toxins produced by micro-organisms (e.g. *Staphylococcus aureus*, *Clostridium botulinum*, *Listeria monocytogenes*, Hepatitis A, Norovirus), marine biotoxins produced by algae or bacteria (e.g. ciguatera toxin (CTX), tetrodotoxin (TTX), paralytic shellfish poisoning toxins (PSP; e.g.

* Corresponding author. Division of Aquaculture and Upgrading (DivAV), Portuguese Institute for the Sea and Atmosphere (IPMA, I.P.), Lisbon, Portugal.
E-mail addresses: amarques@ipma.pt (A. Marques), aluisa@ipma.pt (A.L. Maulvault), mlnunes@ipma.pt (M.L. Nunes).

https://doi.org/10.1016/j.tifs.2018.09.013
Received 29 June 2017; Received in revised form 16 July 2018; Accepted 11 September 2018
Available online 14 September 2018
0924-2244/ © 2018 Elsevier Ltd. All rights reserved.

saxitoxins), diarrheic shellfish poisoning toxins (DSP; e.g. okadaic acid), amnesic shellfish poisoning toxins (ASP; e.g. domoic acid), neurotoxic shellfish poisoning toxins (NSP; e.g. brevetoxins)) and histamine. The global increase of harmful algal blooms (HABs) events (producing e.gASP toxin, PSP toxin, lipophilic toxins like okadaic acid) in coastal areas is threatening the shellfish farming industry and consumers' health (Rodgers et al., 2016). Changes in HABs distribution are linked to climate change effects, such as warmer temperatures, less turbid waters and intense rainfall that favor algae growth. In addition, non-regulated emerging toxins from HABs (e.g. azaspiracids in the Atlantic Europe, pinnatoxins in Norway and Mediterranean Sea, spirolides and gymnodimines in the Mediterranean and Norway, palytoxins in the Mediterranean Sea and the Atlantic Ocean and ciguatoxins both in Madeira and the Canary Islands) have recently become a concern due to their environmental stability, broad distribution, dispersion into new locations, potential biomagnification and toxic effects (Carnicer, Guallar, Andree, Diogène, & Fernández-Tejedor, 2015; Rodgers et al., 2016). For example, the potent neurotoxin tetrodotoxin has been reported in shellfish from UK, Greece and The Netherlands, indicating that consumers might be at risk and strengthening the urgent need to set regulatory limits (EC, 2016). For some toxins, maximum levels are being recommended by food safety authorities (e.g. EFSA, FDA), but are not yet in regulations.

1.2. Chemical contaminants

Chemical contaminants of emerging concern in seafood arise from the utilization of compounds from anthropogenic origin that are released into the environment (Vandermeersch et al., 2015). Some contaminants have potential harmful effects to the ecosystem and consumers, particularly those that are persistent, bioactive and have bioaccumulation potential, thus gaining increasing interest by regulatory authorities. The group of emerging pollutants includes pharmaceuticals (e.g. new veterinary drugs used in aquaculture), personal care products, hormone disrupting substances, brominated flame retardants, toxic elemental species (e.g. organic mercury, inorganic arsenic), perfluorinated compounds, nanomaterials, microplastics, additives, allergens, etc. (Aznar-Alemany et al., 2017; Cunha et al., 2015; Maulvault et al., 2015; Rainieri, Barranco, Primec, & Langerholc, 2017; Vandermeersch et al., 2015; Álvarez-Muñoz et al., 2015). These contaminants are candidates for future regulation, depending on their toxicity, potential health effects, public perception and monitoring data regarding their occurrence. The information currently available on the levels of several emerging environmental contaminants in seafood is either unavailable, fragmented or not harmonized, which may hinder the elaboration of seafood risk assessment. Nonetheless, some chemical contaminants are already well regulated and with monitoring schemes implemented in Europe (e.g. Pb, Cd, Hg, polycyclic aromatic hydrocarbons, polychlorinated biphenyl and dioxins).

2. Research and infrastructure needs

2.1. Research

Seafood production, product availability on the market, dietary habits and the presence of potential hazards are constantly changing. Lack of knowledge may be an important source of uncertainty in the outcome of seafood safety risk assessment, and may result in uncertainties in the conclusions. These uncertainties can be reduced once the missing information is made available through research, surveillance and/or monitoring. Because the problems are largely regional, ideally the primary effective control (except imports) would be at the national or regional level. However, at the national level it is often not possible to assess all those analytes needed to ensure safety in a common EU market, thus favoring control at EU level. This may be performed by universities or institutes with highly specialized expertise, where the capacity to develop new validated fast screening methodologies should be strengthened. In order to ensure transparency and safe seafood, knowledge within the area of seafood safety should be refocused to include:

(i) impacts of climate change on the microbiological safety of fishery products, prevalence of harmful algal blooms and accumulation of chemical contaminants in seafood;
(ii) ADME (Absorption, Distribution, Metabolism, Excretion) of persistent and emerging contaminants (single and multiple) in seafood and consumers;
(iii) resistance of foodborne pathogens (including emerging) to antibiotics from aquaculture and to antibiotics from agriculture in seafood production and processing;
(iv) impacts of non-traditional feed ingredients on farmed seafood quality, safety and nutritional composition;
(v) improvements in methods for risk assessment integrating exposures to multiple chemicals;
(vi) regular updated databases, including data on intakes by the population in different countries and presence and levels of nutrients and contaminants in seafood;
(vii) development of fast screening sensors (e.g. pathogen virulence, environmental contaminants, hormones) for the management of seafood production systems (Leonardo, Reverté, Diogène, & Campàs, 2016);
(viii) mitigation measures to remove/reduce contaminants from seafood (e.g. phycoremediation (Anacleto et al., 2017), processing (Rasmussen et al., 2017), probiotics, bacteriophages);
(ix) measures to increase consumer awareness about the safety of seafood (e.g. seafood quality certification schemes, labels of quality, automated traceability systems, online consumer benefit-risk communication tools).

Cutting-edge and high quality research is vital to better understand the relationship between seafood, nutrition and health, and progress the development of effective strategies to decrease diet-related health issues.

2.2. Infrastructures and technologies

As a rule, traditional tools to assess seafood safety are time consuming and do not cover all safety issues. The European Food Law states that the seafood industry is responsible for implementing Hazard Analyses Critical Control Points (HACCP) in their production lines (EC Regulation No 178/2002 from 28th January). This Regulation also lays down the procedures in matters of seafood safety and established the European Food Safety Authority (EFSA). The HACCP that seafood producers should apply include ensuring that: a) the origin of products is from authorized countries only; b) products are caught by approved vessels or produced in registered farms; c) products are accompanied by proper health certificates; d) HACCP is implemented to ensure the hygiene and safety of products (e.g. EC Regulation No 2073/2005, EC Regulation No 1881/2006); e) the threshold of concern or hazard analysis; and f) strict traceability rules and labelling systems are in place (EU Directive 1379/2013). Within HACCP, the most time consuming task is to test the threshold of the toxicological effect (hazard characterization), which is a task for researchers. Thus, it is of utmost importance to use innovative technologies that enable a better understanding of the unknowns in seafood safety and their validation by official control authorities. This includes, for instance, omics technologies, such as lipidomics, metabolomics and proteomics, as well as real-time and cost-effective fast screening multi-residue tools (e.g. biosensors). Additionally, official control labs should also use such tools to complement the currently expensive official control methods (e.g. gas chromatography coupled to mass spectrometry). Therefore, such solutions may strengthen the confidence of consumers in seafood products

and hence, the competitiveness of European seafood producers. Biosensors are able to monitor seafood quality in a specific way, as they can detect the presence of contaminant molecules and might be designed in a tailored manner according to the type of product being packed. Since food-borne infections are constantly changing over time, accurate, online, in-situ sensing and analysis of contaminants, detection and identification of pathogens, and monitoring of post-processing food quality parameters are rapidly needed (e.g. coupling biosensors to RFID technology).

Integration of fragmented data and tools are also needed to maximise the use of resources employed in seafood safety. Databases where seafood safety data generated, e.g. from monitoring programs and research, can be stored, managed, harmonised, accessed, analysed and interpreted (e.g. pan-EU food surveillance; pan-EU nutritional health) will ensure a close collaboration between official control labs, food safety authorities, industrials and consumers, and an easy access to data. Rational integration of available data will enable a reduction of uncertainties in risk assessment and facilitate decision-making, thus providing prompter answers to future seafood safety crises.

The implementation of regional seafood safety knowledge platforms are also crucial to ensure that the voice of regional specificities are addressed in this field. Such platforms need to integrate a variety of stakeholders, from scientists, health authorities, food safety authorities, industrials, policy makers and consumers, to ensure that transparent, useful and credible visions and needs are addressed in an appropriate and useful way.

Additionally, having in mind the lack of understanding of the nature of risks in the seafood sector by consumers and health professionals, strong campaigns for information, dissemination and education in these matters are needed, particularly for high risk seafood products.

3. Conclusions

Research and infrastructure needs in seafood safety of chemical hazards reviewed here represent how the field is evolving with new knowledge, technologies and data becoming available. The reliance on abundant data using accurate tools and technologically optimized and updated infrastructures is a common trait to ensure low uncertainly in seafood risk assessment. This urges faster exchange of information and establishment of synergies across countries and continents, simplified and efficient food safety policies for stakeholders, innovative and applied research and better understanding of the current unknowns. Addressing such needs will ensure that our society is adapted to the emerging seafood safety challenges in the Ocean of Tomorrow.

Acknowledgements

The research leading to this review has received funding from the European Union Seventh Framework Programme (FP7/2007–2013) under the ECsafeSEAFOOD project (grant agreement n° 311820) and from the H2020 Programme under the SEAFOOD^{TOMORROW} project (grant agreement nº 773400). The Portuguese Foundation for Science and Technology supported the Ph.D. Grant of ALM (SFRH/BD/103569/2014) and the contract of AM under the IF2014 program.

References

Álvarez-Muñoz, D., Rodríguez-Mozaz, S., Maulvault, A. L., Tediosi, A., Fernández-Tejedor, M., Van den Heuvel, F., et al. (2015). Occurrence of pharmaceuticals and endocrine disrupting compounds in macroalgaes, bivalves, and fish from coastal areas in Europe. *Environmental Research, 143*, 56–64.

Anacleto, P., van den Heuvel, F. H. M., Oliveira, C., Rasmussen, R. R., Fernandes, J. O., Sloth, J. J., et al. (2017). Exploration of the phycoremediation potential of *Laminaria digitata* towards diflubenzuron, lindane, copper and cadmium in a multitrophic pilot-scale experiment. *Food and Chemical Toxicology, 104*, 95–108.

Aznar-Alemany, O., Trabalón, L., Jacobs, S., Barbosa, V. L., Fernández Tejedor, M., Granby, K., et al. (2017). Occurrence of halogenated flame retardants in commercial seafood species available in European markets. *Food and Chemical Toxicology, 104*, 35–47.

Behravesh, C. B., Williams, I. T., & Tauxe, R. V. (2012). Emerging foodborne pathogens and problems: Expanding prevention efforts before slaughter or harvest. *Institute of medicine (US). Improving food safety through a one health approach: Workshop summary*. Washington (DC): National Academies Press (US).

Carnicer, O., Guallar, C., Andree, K. B., Diogène, J., & Fernández-Tejedor, M. (2015). *Ostreopsis cf. ovata* dynamics in the NW Mediterranean Sea in relation to biotic and abiotic factors. *Environmental Research, 143*, 89–99.

Cunha, S. C., Fernandes, J. O., Vallecillos, L., Cano-Sancho, G., Domingo, J. L., Pocurull, E., et al. (2015). Co-occurrence of musk fragrances and UV-filters in seafood and macroalgae collected in European hotspots. *Environmental Research, 143*, 65–71.

EC (2016). *Policy Guideline on tetrodotoxin in live bivalve molluscs.* Communication from the European Commission - TRIS/(2016) 01157http://ec.europa.eu/growth/tools-databases/tris/en/search/?trisaction=search.detail&year=2016&num=175.

Leonardo, S., Reverté, L., Diogène, J., & Campàs, M. (2016). Biosensors for the detection of emerging marine toxins. In D. P. Nikolelis, & G.-P. Nikoleli (Eds.). *Biosensors for security and bioterrorism applications* (pp. 231–248). Springer.

Marques, A., Nunes, M. L., Moore, S. K., & Strom, M. S. (2010). Climate change and seafood safety: Human health implications. *Food Research International, 43*, 1766–1779.

Maulvault, A. L., Anacleto, P., Barbosa, V., Sloth, J. J., Romme Rasmussen, R., Tediosi, A., et al. (2015). Toxic elements and speciation in seafood samples from different contaminated sites in Europe. *Environmental Research, 143*, 72–81.

Mead, P. S., Slutsker, L., Dietz, V., McCaig, L. F., Bresee, J. S., Shapiro, C., et al. (1999). Food-related illness and death in the United States. *Emerging Infectious Diseases, 5*, 607–625.

Rainieri, S., Barranco, A., Primec, M., & Langerholc, T. (2017). Occurrence and toxicity of musks and UV filters in the marine environment. *Food and Chemical Toxicology, 104*, 57–68.

RASFF (2016). *The Rapid alert system for food and feed: 2015 annual report.* European Commission. Health and Food Safety.

Rasmussen, R. R., Søndergaard, A. B., Bøknæs, N., Cederberg, T. L., Sloth, J. J., & Granby, K. (2017). Effects of industrial processing on essential elements and regulated and emerging contaminant levels in seafood. *Food and Chemical Toxicology, 104*, 85–94.

Rodgers, C., & Diogène, J. (2016). Microbiological and toxin outbreaks in seafood. Chapter 10. In J. M. Soon, L. Manning, & C. A. Wallace (Eds.). *Foodborne diseases. Case studies of outbreaks in the agri-food industries* (pp. 189–240). CRC Press by Taylor & Francis Group.

Vandermeersch, G., Lourenço, H. M., Alvarez-Muñoz, D., Cunha, S., Diogène, J., Cano-Sancho, G., et al. (2015). Environmental contaminants of emerging concern in seafood – European database on contaminant levels. *Environmental Research, 143*, 29–45.